

HOST CHECKLIST OF ROOT-KNOT NEMATODES ON BROAD-LEAVED LANDSCAPE TREES

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Abstract. A comprehensive review of the world literature dealing with root-knot nematodes (*Meloidogyne* spp.) on landscape trees is presented, including both natural occurrence and positive and negative results of controlled inoculations. Information is provided on more than 120 species in 56 plant genera.

Résumé. Une revue détaillée de la littérature mondiale s'intéressant aux nématodes des racines (*Meloidogyne* spp.) sur les arbres d'ornement est présentée, incluant la présence naturelle et les résultats positifs et négatifs d'inoculations contrôlées. Des renseignements sont fournis sur plus de 120 espèces de 56 genres de plantes.

Earlier this year, we published (65) the results of our rather extensive studies of root-knot nematodes (*Meloidogyne* spp.) on willows (*Salix* spp.). While we were surveying the world literature on this topic, it became obvious that although there had been numerous reports of root-knot nematodes on woody plants there were also great gaps in our knowledge of the exact identity of the pest and host species. Furthermore, it was apparent that there would be opportunities for significant observational and experimental research in this field if persons working with trees were aware of past investigations.

All of the root-knot nematodes are currently classified in the genus *Meloidogyne*. Although the genus had been established by E.A. Goeldi in 1887 for *M. exigua* (on coffee trees in Brazil), subsequent authors placed other root-knot nematodes under the genera *Anguillula*, *Caconema*, *Heterodera*, and *Oxyuris*. It was not until 1949 (14) that B.G. Chitwood re-established the genus, redescribing *M. exigua* (Goeldi) Chitwood, *M. arenaria* (Neal) Chitwood, *M. incognita* (Kofoid and White) Chitwood, and *M. javanica* (Treub) Chitwood and describing a new species (*M. hapla* Chitwood). These are still considered the most widespread and destructive root-knot nematodes throughout temperate zones around the world. Their host ranges include herbaceous and woody plants in field, orchard, and forest, but major research efforts have been restricted to important economic crops such as tobacco, tomato,

potato, soybean, strawberry, and cotton.

Some morphological variants of these species have been described as subspecies or varieties, usually expressed as trinomials: *M. arenaria thamesi*, *M. incognita acrita*, and *M. javanica bauruensis*. In the 1976 compendium of Esser, *et al.* (20), these three subspecific taxa were elevated to species rank.

A somewhat more biologically important classification has been developed by Sasser (66), who distinguished "races" among these species based on their ability to infest and reproduce on different host plant cultivars. He recognized four races of *M. incognita*, two of *M. arenaria*, and only a single race of *M. hapla* and *M. javanica*. A further differentiation of two races of *M. hapla* was made by Triantaphyllou and Hirschmann (76) on the basis of chromosome numbers and mode of reproduction. Sasser (66) stated that the host races of *M. arenaria* and *M. incognita* were morphologically indistinguishable (within species). It is of some interest that the culture of *M. arenaria* that Chitwood (14) obtained from W.H. Thames (*M. arenaria thamesi*) did not infect peanut and, perhaps, could be equated with *M. arenaria* (Race 2) of Sasser (66). Despite these studies on morphology, cytology, and host preference, most of the current nematological research is concerned with the utilization or identification of these organisms at the species level.

Of the 35 *Meloidogyne* "species" listed by Esser *et al.* (20) in 1976, only three new species had been reported on woody host genera commonly grown in the United States. These were *M. brevicauda* Loos on tea (*Camellia sinensis* (L.) Kunze) in 1953 in Ceylon (41), *M. ovalis* Riffle on sugar maple and other trees in 1963 in Wisconsin (60), and *M. mali* Itoh, Ohshima, and Ichinohe on apple (*Malus*) and other trees in 1969 in Japan (34). Neither *M. brevicauda* nor *M. mali* have been found in the United States but *M. ovalis* has been subsequently reported from Iowa (57).

Since 1976, several new *Meloidogyne* species

have been reported on woody hosts. Golden (24) described *M. camelliae* Golden on *Camellia japonica* L. imported from Japan and *M. querciana* Golden on pin oak (*Quercus palustris* Muenchh.) from Virginia (1979). Hirschmann (32), in 1982, described *M. platani* Hirschmann from sycamore (*Platanus occidentalis* L.) in Virginia and *M. christiei* Golden and Kaplan (25) was reported on *Quercus laevis* Walt. in Florida in 1986.

Based on inoculation studies conducted by the nematologists who described these new root-knot nematodes from woody plants, these *Meloidogyne* species have a restricted host range and do not parasitize many herbaceous crop plants. Thus, it is likely that more "new" nematode species will be discovered on woody plants. Some may be found on trees or shrubs previously reported as hosts of "unidentified" *Meloidogyne* species and some could be found on woody plants not previously noted as hosts of any root-knot nematodes.

The compendia issued by the Commonwealth Agricultural Bureaux and other agencies in England [(28)—1940; (26)—1959; (27)—1965] and that of Ruehle (62) in 1967 were invaluable in preparing this checklist. However, insofar as it was possible, all primary references were obtained and checked for accuracy, especially with regard to the nomenclature of host plants. Some original references could not be obtained and these are noted in "Literature Cited".

This checklist is presented to stimulate arborists, horticulturists, and nurserymen to be more aware of the potential damage caused by root-knot nematodes, to "look underground" when investigating the causes of poor plant performance, and to help in extending our knowledge of the diversity and distribution of these plant pests.

In this checklist, the plant species are recorded as being "noted hosts" or "natural hosts" of identified or unidentified or unidentified root-knot nematodes. We have tried to restrict the use of "natural host" to those situations where a particular nematode was found to be capable of completing its life cycle (to reproduce) on the host. The term "noted host" denotes only that root galls were observed.

Acer

- A. japonicum* Thunb.—Noted host of unidentified *Meloidogyne* sp. intercepted in USA on plants from Japan (71).
- A. macrophyllum* Pursh—Noted host of unidentified *Meloidogyne* sp. in Oregon (9).
- A. negundo* L.—Susceptible to inoculation with *M. ovals* (60, 61). Noted host of unidentified *Meloidogyne* sp. in USSR (78).
- A. palmatum* Thunb.—Noted host of *M. mali* in Japan (34).
- A. platanoides* L.—Susceptible to inoculation with *M. ovals* (60, 61). Noted host of unidentified *Meloidogyne* sp. on nursery stock imported into Finland (39).
- A. rubrum* L.—Susceptible to inoculation with *M. ovals* (60, 61). Not susceptible to inoculation with *M. arenaria*, *M. hapla*, *M. incognita*, or *M. javanica* (64); or *M. platani* (32). Noted host of unidentified *Meloidogyne* sp. in Tennessee (63).
- A. saccharum* Marsh.—Natural host of *M. ovals* in Wisconsin and susceptible to inoculation (60, 61). Symptoms included chlorotic foliage, twig dieback and plant death.

Aesculus

- A. hippocastanum* L.—Noted host of unidentified *Meloidogyne* sp. on nursery stock imported into Finland (39).

Albizia

- A. julibrissin* Durazz.—Susceptible to inoculation with *M. arenaria* and *M. arenaria thamesi*; formed galls with *M. hapla*, but no egg masses; not susceptible to inoculation with *M. incognita*, *M. incognita acrita*, or *M. javanica* (67). Heavy galling noted with *M. javanica* and slight galling with *M. incognita* (23).
- A. lebbek* Benth.—Natural host of *M. javanica* in Africa (47). Other tropical species are also hosts of *M. incognita*.

Ainus

- A. japonica* Sieb. & Zucc.—Noted host of unidentified *Meloidogyne* sp. on imported stock in Maryland (73).

Betula

- B. alleghaniensis* Britt.—Susceptible to inoculation with *M. ovals* (60, 61).
- B. maximowicziana* Regel—Noted host of *M. mali* in Japan (69).
- B. nigra* L.—Natural host of unidentified *Meloidogyne* sp. in Georgia (63). Not susceptible to inoculation with *M. ovals* (61).
- B. papyrifera* Marsh.—Susceptible to inoculation with *M. ovals* (60, 61).

Broussonetia

- B. kazinoki* Sieb.—Noted host of unidentified *Meloidogyne* sp. (12).
- B. papyrifera* (L.) Vent.—Noted host of unidentified *Meloidogyne* sp. in Florida (55).

Camellia

- C. japonica* L.—Noted host of *M. camelliae* on material sent to USA from Japan and susceptible to inoculation (24).
- C. sinensis* (L.) Kunze—"Tea"—Noted host of four major *Meloidogyne* sp. and also of *M. brevicauda* Loos in Ceylon (41).

Camellia sp.—Noted host of *M. incognita acrita* in South Carolina (5) and of unidentified *Meloidogyne* sp. in Texas and Georgia (5), and North Carolina (31).

Carpinus

C. betulus L.—Noted host of unidentified *Meloidogyne* sp. in Italy (77).

Carya

C. illinoensis (Wang.) K. Koch—Noted host of *M. incognita acrita* in Alabama (5).

Castanea

C. crenata Sieb. & Zucc.—Noted host of *M. mali* in Japan (34).

C. dentata Borkh.—Susceptible to inoculation with *M. querciana* (24).

C. mollissima Blume—Noted host of unidentified *Meloidogyne* sp. in Georgia (5).

C. sativa Mill.—Noted host of unidentified *Meloidogyne* sp. (77).

Catalpa

C. bignonioides Walt.—Noted host of unidentified *Meloidogyne* sp. in USSR (78) and Israel (49).

C. ovata G. Don—Noted host of unidentified *Meloidogyne* sp. in Maryland (46).

C. speciosa Warder—Noted host of unidentified *Meloidogyne* sp. (10, 13). Not susceptible to inoculation with *M. ovalis* (61).

Catalpa sp.—Noted host of *M. incognita* and *M. incognita acrita* in Alabama (5). Plants imported into Canada from Holland were infested with *M. arenaria* (6).

Celtis

Celtis sp.—Not susceptible to inoculation with *M. ovalis* (61).

Chaenomeles

C. speciosa (Sweet) Nakai—Noted host of unidentified *Meloidogyne* sp. (81).

Clerodendron

C. trichotomum Thunb.—Noted host of unidentified *Meloidogyne* sp. (13).

C. ugandense Prain—Natural host of *M. incognita* in Australia (17).

Clerodendron sp.—Natural host of *M. arenaria* in Africa (47). Many tropical species have been noted as host of unidentified *Meloidogyne* sp.

Cornus

C. alba L.—Noted host of unidentified *Meloidogyne* sp. on nursery stock imported into Finland (39).

C. florida L.—Noted host of *M. hapla* (70). Noted host of *M. incognita* in Georgia (36) and Florida (40). Symptoms included tip burn, premature leaf drop, and stunting. Considered resistant to *M. incognita acrita* (18). Not susceptible to inoculation with *M. platani* (1, 32).

Crataegus

C. pyracantha—Cited as such in Goodey (27) but original reference was to an unidentified *Meloidogyne* sp. on *Pyracantha coccinea* Roem. (4).

Cydonia

C. oblonga Mill. (= *C. vulgaris* Pers.)—Noted host of unidentified *Meloidogyne* sp. (10, 49).

Dalbergia

D. sisso Roxb.—Natural host of *M. javanica bauruensis* in Israel (51).

Diospyros

D. kaki L.—Noted host of unidentified *Meloidogyne* sp. (10).

D. virginiana L.—Noted host of unidentified *Meloidogyne* sp. (10).

Elaeagnus

Elaeagnus sp.—Natural host of unidentified *Meloidogyne* sp. in Israel (51).

Euonymus

E. alatus (Thunb.) Sieb.—Noted host of unidentified *Meloidogyne* sp. (54).

E. japonicus Thunb.—Noted host of unidentified *Meloidogyne* sp. in USSR (78). Cultivar 'Albo-marginatus' was noted host of *M. javanica* (48).

Fraxinus

F. americana L.—Natural host of *M. ovalis* in Wisconsin (60), but no egg masses were found following artificial inoculation (61). Susceptible to inoculation with *M. platani* showing moderate to high galling and moderate egg production (1, 32). Noted host of unidentified *Meloidogyne* sp. in USSR (78).

F. mandshurica Rupr.—Noted host of unidentified *Meloidogyne* sp. (13).

F. nigra Marsh.—Noted host of unidentified *Meloidogyne* sp. (13).

F. oxycarpa Willd. (= *F. oxyphylla* Bieb.)—Natural host of *M. javanica* in Israel (50).

F. pennsylvanica Marsh.—Not susceptible to inoculation with *M. ovalis*; numerous galls were formed but no egg masses (61).

F. retusa Champ.—Noted host of *M. incognita* in Taiwan (79).

F. syriaca Boiss.—Natural host of *M. javanica* in Israel (50).

F. velutina Torr.—Noted host of unidentified *Meloidogyne* sp. (16).

Fraxinus sp.—Noted host of *M. ovalis* in Iowa (57). Noted host of unidentified *Meloidogyne* sp. in Oklahoma (5).

Ginkgo

G. biloba L.—Noted host of unidentified *Meloidogyne* sp. in Mississippi (72).

Gleditsia

G. triacanthos L.—Noted host of unidentified *Meloidogyne* sp. in USSR (78). Not susceptible to inoculation with *M. ovalis* (61).

Ilex

I. cornuta Lindl. 'Dwarf Burford' and 'Rotunda'—Noted host of *M. arenaria* following artificial inoculation (8).

I. crenata Thunb.—Noted host of *M. arenaria* in Georgia (5), of *M. hapla* and *M. incognita* in North Carolina (31), of *M. incognita acrita* in North Carolina and Virginia (5), and of *M.*

javanica in Virginia (5). Cultivars 'Compacta', 'Convexa', 'Helleri', and 'Rotundifolia' were noted hosts of *M. arenaria* following artificial inoculation (8).

- I. opaca* Ait.—Noted host of *M. arenaria* following artificial inoculation (8). Noted host of *M. incognita* in Alabama (5).
I. vomitoria Ait. 'Nana'—Noted host of *M. arenaria* following artificial inoculation (8).

Juglans

- J. cinerea* L.—Noted host of unidentified *Meloidogyne* sp. in Florida (13, 55).
J. nigra L.—Noted host of *M. ovalis* in Iowa (57). Noted host of unidentified *Meloidogyne* sp. (13).
J. regia L.—Noted host of *M. javanica* in Israel (53) and of *M. arenaria* in Czechoslovakia (74). Noted host of unidentified *Meloidogyne* sp. in Florida (55).
J. rupestris Engelm.—Noted host of unidentified *Meloidogyne* sp. in Arizona (10).

Koelreuteria

- K. paniculata* Laxm.—Noted host of unidentified *Meloidogyne* sp. in USSR (68).

Laburnum

- L. anagyroides* Medic.—Noted host of *M. hapla* in Maryland; based on soil samples, not galls (44).

Liquidambar

- L. styraciflua* L.—Not susceptible to inoculation with *M. arenaria*, *M. hapla*, *M. incognita*, *M. javanica* (64), or *M. platani* (1, 32). Noted host of unidentified *Meloidogyne* sp. in Mississippi (5, 81).

Liriodendron

- L. tulipifera* L.—Natural host of *M. javanica* in Georgia and susceptible to inoculation (64). Symptoms included wilting and stunted growth of seedlings. Not susceptible to inoculation with *M. arenaria*, *M. hapla*, *M. incognita* (64), or *M. platani* (1, 32).

Magnolia

- M. grandiflora* L.—Noted host of unidentified *Meloidogyne* sp. in Georgia (45).
Magnolia sp.—Noted host of unidentified *Meloidogyne* sp. in Florida, Georgia (5), and Arizona (11).

Malus

- M. baccata* (L.) Borkh.—Noted host of unidentified *Meloidogyne* sp. on nursery stock imported into Finland (39).
M. x domestica Borkh.—Noted host of unidentified *Meloidogyne* sp. on nursery stock imported into Finland (39).
M. prunifolia (Willd.) Borkh.—Noted host of *M. mali* in Japan (34).
M. pumila Mill.—Noted host of *M. mali* in Japan (34).
M. sieboldii (Reg.) Rehd.—Noted host of *M. mali* in Japan (34).
M. sylvestris Mill.—Noted host of *M. incognita* and *M. javanica* on Norfolk Island, Australia (38); and (as *Malus mitis*) an unidentified *Meloidogyne* sp. in Israel (49).
Malus sp.—Not susceptible to inoculation with *M. ovalis* (61).

Melia

- M. azedarach* L.—Noted host of unidentified *Meloidogyne* sp. in USA (10, 11, 12).

Morus

- M. alba* L.—Natural host of *M. javanica* in Queensland, Australia (17). Noted host of *M. incognita* in Iraq (33) and an unidentified *Meloidogyne* sp. in Israel (49).
M. bombycis Koidz.—Noted host of *M. mali* in Japan (34).
M. indica L.—Noted host of *M. javanica* in northern India (56).
M. nigra L.—Noted host of unidentified *Meloidogyne* sp. (10, 13).
M. rubra L.—Noted host of unidentified *Meloidogyne* sp. (10, 13).
Morus sp.—Natural host of *M. arenaria* and noted host of *M. hapla*, *M. incognita acrita* (51) and *M. javanica* (52) in Israel.

Paulownia

- P. fortunei* Hemsl.—Susceptible to inoculation with *M. incognita* (80).

Pistacia

- P. vera* L.—Noted host of *M. incognita* in Iraq (33) and an unidentified *Meloidogyne* sp. in California (37).

Platanus

- P. x acerifolia* (Ait.) Willd.—Natural host of unidentified *Meloidogyne* sp. in Washington, DC (15); later identified as *M. platani*.
P. occidentalis L.—Natural host (nursery origin) of *M. platani* in Virginia and susceptible to inoculation (1, 32). Not susceptible to inoculation with *M. arenaria*, *M. hapla*, *M. incognita*, or *M. javanica* (64).

Populus

- P. alba* L.—Natural host of *M. javanica* in Israel (50).
P. deltoides Marsh.—Natural host of unidentified *Meloidogyne* sp. in South Carolina (63).
P. heterophylla L.—Not susceptible to inoculation with *M. arenaria*, *M. hapla*, *M. incognita*, or *M. javanica* (64).
Populus sp.—Noted host of *M. incognita* and *M. incognita acrita* in Israel (51).

Prunus

- P. amygdalus* Batsch.—"Almond"—Noted host of *M. hapla* (52), *M. incognita* (50, 51), *M. incognita acrita* (43, 51), and *M. javanica* 21, 75).
P. armeniaca L.—"Apricot"—Noted host of *M. incognita acrita* and *M. javanica* (43).
P. avium L.—"Sweet Cherry"—Noted host of unidentified *Meloidogyne* sp. (12).
P. cerasifera Ehrh.—"Cherry Plum"—Noted host of unidentified *Meloidogyne* sp. (55).
P. cerasus L.—"Sour Cherry"—Noted host of *M. hapla* (44) and *M. javanica* (50).
P. davidiana (Carr.) Franch.—Noted host of unidentified *Meloidogyne* sp. (13).
P. domestica L.—"Plum"—Noted host of *M. incognita* in Iraq (33), and of unidentified *Meloidogyne* sp. (11, 55).
P. japonica Thunb. Noted host of unidentified *Meloidogyne* sp. (55).
P. mahaleb L.—Noted host of unidentified *Meloidogyne* sp. (58).
P. persica (L.) Batsch.—"Peach"—Abundant literature; not included here.
P. serotina Ehrh.—Not susceptible to inoculation with *M. ovalis* (61).

- P. virginiana* L.—Noted host of unidentified *Meloidogyne* sp. (10, 13).
P. yedoensis Matsum.—Natural host of *M. mali* in Japan (34).

Pyrus

- P. communis* L.—Noted host of *M. incognita acrita* (42). Noted host of unidentified *Meloidogyne* sp. (10, 13).

Quercus

- Q. agrifolia* Nee—Noted host of unidentified *Meloidogyne* sp. (12).
Q. falcata Michx.—Erroneously used as a synonym for *Q. laevis*, the host of *M. christiei* (25).
Q. laevis Walt.—Natural host of *M. christiei* in Florida (25); unusual spherical galls on the sides of the roots.
Q. palustris Muenchh.—Natural host of *M. querciana* in Virginia; and susceptible to inoculation (24). Not susceptible to inoculation with *M. incognita incognita* or *M. incognita acrita* (24).
Q. rubra L.—Susceptible to inoculation with *M. querciana* (24), shoot growth was visibly affected. Not susceptible to inoculation with *M. incognita incognita* or *M. incognita acrita* (24).
Q. suber L.—Noted host of unidentified *Meloidogyne* sp. in France (19) and USA (12).
Q. virginiana Mill.—Not susceptible to inoculation with *M. ovalis* (61).
Quercus sp.—Noted host of unidentified *Meloidogyne* sp. on oak seedlings in Arizona (11).

Robinia

- R. pseudoacacia* L.—Susceptible to inoculation with *M. incognita* (80); not susceptible to inoculation with *M. ovalis* (61). Noted host of unidentified *Meloidogyne* sp. in Oklahoma (5, 12) and Israel (49).

Salix

- (See recent work of Santamour and Batzli (65)).

Sambucus

- S. nigra* L.—Noted host of unidentified *Meloidogyne* sp. (12, 29).

Sapindus

- S. saponaria* L.—Noted host of unidentified *Meloidogyne* sp. in USSR (78).

Sophora

- S. japonica* L.—Noted host of unidentified *Meloidogyne* sp. in USSR (78).

Sorbus

- S. americana* Marsh.—Noted host of *M. arenaria* on stock imported from Holland (7).

Stewartia

- S. malacodendron* L.—Noted host of unidentified *Meloidogyne* sp. (13).

Styrax

- S. dasyanthus* Perk.—Noted host of unidentified *Meloidogyne* sp. (12).

- S. veitchiorum* Hemsl.—Noted host of unidentified *Meloidogyne* sp. (12).

Syringa

- S. dilatata* Nakai—Noted host of unidentified *Meloidogyne* sp. (13).
S. sweginzowii Koehne & Lingelsh.—Noted host of unidentified *Meloidogyne* sp. (3).
S. vulgaris L.—Mistakenly reported by Goodey (27) as a host of an unidentified *Meloidogyne* sp. Goodey's information came from Martin (46), which was erroneously referenced as Cobb (16). Martin (46) reported the unidentified nematode on *Philadelphus* sp., for which "syringa" is a common name.

Tilia

- Tilia cordata* Mill.—Noted host of unidentified *Meloidogyne* sp. on nursery stock imported to Finland (39).

Ulmus

- U. americana* L.—Natural host of *M. ovalis* in Wisconsin (60), and susceptible to inoculation with *M. ovalis* (61). Noted host of unidentified *Meloidogyne* sp. in Oklahoma (5).
U. glabra Huds.—Noted host of *M. hapla* on roots of trees from Holland (30). Small galls were uniformly distributed throughout root system.
U. parvifolia Jacq.—Noted host of unidentified *Meloidogyne* sp. (28).
U. procera Salisb.—Noted host of unidentified *Meloidogyne* sp. (10).
U. pumila L.—Noted host of unidentified *Meloidogyne* sp. in USSR (78).
U. rubra Michx. (= *U. fulva* Michx.)—Not susceptible to inoculation with *M. ovalis* (61).
Ulmus sp.—Noted host of *M. arenaria* and *M. incognita* in the Netherlands (59) and an unidentified *Meloidogyne* sp. in Oklahoma (12).

Zelkova

- Z. serrata* (Thunb.) Makino—Noted host of *M. incognita* and *M. javanica* in Taiwan (79).

Zizyphus

- Z. mucronata* Willd.—Noted host of unidentified *Meloidogyne* sp. in Southern Rhodesia (35).

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